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The (lack of) effect of dynamic visual noise on the concreteness effect in short-term memory

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ABSTRACT
It has been suggested that the concreteness effect in short-term memory (STM) is a consequence of concrete words having more distinctive and richer semantic representations. The generation and storage of visual codes in STM could also play a crucial role on the effect because concrete words are more imaginable than abstract words. If this were the case, the introduction of a visual interference task would be expected to disrupt recall of concrete words. A Dynamic Visual Noise (DVN) display, which has been proven to eliminate the concreteness effect on long-term memory (LTM), was presented along encoding of concrete and abstract words in a STM serial recall task. Results showed a main effect of word type, with more item errors in abstract words, a main effect of DVN, which impaired global performance due to more order errors, but no interaction, suggesting that DVN did not have any impact on the concreteness effect. These findings are discussed in terms of LTM participation through redintegration processes and in terms of the language-based models of verbal STM.

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Verbal short-term memory; concreteness effect; dynamic visual noise; visual interference

It is well known that concrete words (e.g., tree) are processed faster and more accurately than abstract words (e.g., kindness). This advantage is referred to as the *concreteness effect*, and can be found in a variety of tasks such as naming (Strain, Patterson, & Seidenberg, 1995), paired-associate learning (Paivio, Yuille, & Smythe, 1966), lexical decision (Binder, Westbury, McKiernan, Possing, & Medler, 2005), free recall (Paivio, Walsh, & Bons, 1994; Richardson, 2003), cued recall (Paivio et al., 1994), recognition (Fliessbach, Weis, Klaver, Elger, & Weber, 2006; Peters & Daum, 2008), and short-term memory (STM; Walker & Hulme, 1999). In the domain of STM, it has been suggested that the effect is a consequence of concrete words having more distinctive and richer semantic representations (Acheson, Postle, & MacDonald, 2010; Allen & Hulme, 2006; Romani, McAlpine, & Martin, 2008; Walker & Hulme, 1999). This statement supports the idea of the participation of semantic factors in STM and is congruent with the context availability model (Schwanenflugel & Shoben, 1983), which assumes that concrete words are more connected to semantic contents and are capable of activating more semantic information.

One of the first studies that indirectly demonstrated the implication of semantic factors in STM was Tehan and Humphreys' (1988), who compared the recall of content words (nouns or adjectives) with function words with low semantic value (articles or prepositions), finding an advantage for the former. Later on, however, Bourassa and Besner (1994) claimed that the effect disappeared when controlling for imageability. In this line, some studies have suggested that the semantic advantage of concrete words as opposed to abstract words could be due to the fact that concrete words can evoke mental images, so that memory performance may be supported by visual representations (Paivio, 1986; Paivio, Yuille, & Madigan, 1968). From this view, the concreteness effect in STM would arise from concrete words activating and benefiting from non-verbal (visual) additional representations.

If the advantage of concrete words as opposed to abstract words in STM is mainly due to the involvement of visual codes, it can be expected that the introduction of a concurrent visual-interference task would disrupt concrete words selectively in a serial recall task. One of the concurrent passive visual interference techniques that would be suitable to test this assumption is the Dynamic Visual Noise (DVN). The DVN technique was developed by Quinn and McConnell (1996), and consists of presenting an array of small black and white squares on a computer screen, which change randomly from black to white and vice versa. DVN has been suggested to interfere with the recall of auditorily presented verbal information, with an increase in DVN complexity producing a greater disruption on recall (McConnell & Quinn, 2000, 2004; Quinn & McConnell, 1996). Quinn and McConnell argued that this particular interference reflects a direct access to visual working memory of perceived visual information, and that DVN can be seen as an irrelevant visual interference because its lack of visual structure is unlikely

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to activate meaningful representations from long-term memory (LTM). However, other studies suggest that DVN could potentially affect the generation of mental images but not visual memory *per se*; in other words, DVN might have an effect on memory tasks that rely on visual imagery, without accessing the visual memory system (Andrade, Kemps, Werniers, May, & Szmalec, 2002; Avons & Sestieri, 2005; Logie, 2003). In this line, it has been shown that DVN reduces reported vividness of imagined objects or scenes (Baddeley & Andrade, 2000, Experiment 6), and interferes with the formation of mental images in both the Brooks spatial matrix task (Toms, Morris, & Foley, 1994) and the size comparison task (Dean, Dewhurst, Morris, & Whittaker, 2005). The DVN technique, therefore, could be a good candidate for exploring the influence of visual imagery on the concreteness effect.

Parker and Dagnall (2009) directly tested this assumption within the domain of LTM, in a study that included free recall and recognition of concrete and abstract words. During the encoding phase, one group of participants listened to the words while looking at a DVN field, whereas another group (the control group) had to look at a static visual noise field (a display with black and white squares that do not change). In the free-recall experiment, they found the expected concreteness effect in the static visual noise condition but, interestingly, the effect was reversed in the DVN condition. The reversion of the effect was a consequence of the fact that the visual noise interference selectively impaired recall of concrete words, whereas visual interference had no effect on the recall of abstract words. In order to determine whether this effect would generalise to other memory tests, they employed a recognition task in a second experiment and, again, they found an inversion of the concreteness effect in the DVN condition. These findings suggest a selective interference in the processing of visual images during encoding in LTM tasks, and support Paivio's description of connections between logogens and imagens (Paivio, 1986). According to this view, memory for concrete words is reduced because the interference disrupts the activation of the imagen, which in turns disrupts logogen's processing and activation.

In STM studies, however, although the implication of semantic codes has been explored (Campoy & Baddeley, 2008; Monnier & Syssau, 2008; Walker & Hulme, 1999), there is no clear evidence that concrete words advantage could also be mainly attributable to the involvement of visual codes. Although not directly addressing this issue, Campoy, Castellà, Provencio, Hitch, and Baddeley (2015) provided preliminary evidence in a study that aimed at testing the effects of attention-demanding concurrent tasks on the concreteness effect in STM. In Experiment 3, they included two different concurrent tasks that involved visuospatial interference. In the polygons task, three irregular polygons were presented with each to-be-remembered word and participants had to discriminate which one was different from the other two. In the arrow task, three arrows were presented in the screen with each word, and participants had to reproduce their direction by pressing the corresponding arrow key. Although the introduction of concurrent tasks reduced the global level of memory performance, results showed that the concreteness effect in conditions with concurrent tasks was equivalent to that found in a control condition without concurrent tasks. The study, thus, did not reveal a selective interference on concrete words with visuospatial interference, which seems to indicate that the strategies used by the participants were not mainly based on the generation of mental images.

Somewhat conflicting results were found by Ueno and Saito (2013), who investigated the effect of introducing DVN interference in two tasks involving the immediate recall of concrete and abstract words; these tasks were a paired-associate memory task and an immediate serial recall task. Importantly, in both tasks participants were instructed to use rote rehearsal in order to minimise the intentional use of visual images. Results revealed a smaller concreteness effect on the serial recall task compared to the paired-associate task, and a global detrimental effect of DVN on memory performance in the paired-associate task. However, DVN interference did not have a detrimental effect on performance in the serial recall task, which is consistent with the idea that serial recall relies mainly on phonological coding, and also with previous findings that show no effect of DVN on serial order recall when participants are instructed not to use imagery but rote rehearsal (Andrade et al., 2002; Quinn & McConnell, 1996, 2006). On the other hand, when an item correct score was taken into account (a score that only considered the identity of the recalled items, regardless of order and cue-target correctness), the introduction of DVN in the serial recall task tended to have a larger effect for high-concreteness words than for low-concreteness words, although only a marginal effect was found. It should be noted that participants in this study were explicitly instructed to use rote rehearsal and not to create mental images, which in principle could attenuate the influence of visual representations. An additional condition without instructing a particular strategy at encoding would have been necessary in order to disentangle the participation of visual codes and the effect of DVN on item recall. Besides, word lists in the serial recall task were relatively long (8 words per list); a list length that exceeds STM capacity (Cowan, 2010) and that perhaps fostered the contribution of LTM processes.

In the present study, we wanted to explicitly test whether the presentation of DVN during the encoding phase reduces or eliminates the concreteness effect in verbal STM, as it seems to be the case in LTM tasks (Parker & Dagnall, 2009). The present approach differs from that in Campoy et al. (2015) in that visual interference is passive in nature, and does not appear in the context of an attention-demanding task. On the other hand, in contrast to Ueno and Saito (2013), we used shorter word lists (five-word) for immediate serial recall, and tested participants in a more standard STM task with no instructed encoding/maintenance strategy. In addition to our main objective, we explored possible differential effects of concreteness and DVN on item memory and order memory by separately analysing item and order errors.

Experiment 1

In Experiment 1, participants were shown lists of abstract and concrete nouns for immediate serial recall under two encoding condition: with and without (grey screen) DVN interference. The aim was to determine whether visual, non-demanding interference reduced or eliminated the advantage of concrete over abstract words. If immediate recall of concrete words is a consequence of the generation of mental images providing additional information at retrieval, a reduction of the concreteness effect in the DVN condition should be expected. Because our objective was to examine the effect of DVN on stimulus encoding, visual interference was displayed during the presentation of the to-be-remembered words, but not at the recall phase. Presenting visual interference at encoding only was also the procedure followed in previous related studies (Campoy et al., 2015; Parker & Dagnall, 2009; Ueno & Saito, 2013).

Methods

Participants

Forty-eight undergraduate students from the University of Murcia (Spain) took part in the experiment for course credit. All participants in this and the following experiment were native Spanish speakers.

Stimuli and apparatus

We used the LEXESP database (Sebastián, Martí, Carreiras, & Cuetos, 2000) to choose 13 concrete, high-imageability words and 13 abstract, low-imageability words. All the words were trisyllabic Spanish nouns with the stress on the penultimate syllable. Concrete and abstract words were globally matched for word frequency, familiarity, and number of phonemes. All the words, spoken in a neutral tone by a female speaker, were digitally recorded and segmented into individual sound files. Further description of the word sets used in this and the next experiment can be found in Campoy et al. (2015).

The characteristics of the DVN were equivalent to those in Parker and Dagnall (2009). The visual noise pattern consisted of a full screen display of 128 by 128 black and white dots changing randomly from black to white and vice versa at a rate of 2048 changing dots every 250 ms. This yielded a rate of change of 50% per second, following Dean et al. (2005). Dots were 10 pixels wide by 8 pixels high, and the rate of black and white dots was maintained at 50% throughout the presentation.

Experimental software written in E-Prime (Schneider, Eschman, & Zuccolotto, 2002) controlled the experiment, which was run on a computer with a 19-inch monitor. Screen resolution was set at 1280 by 1024 pixels. A headset with microphone was used to present stimuli and record verbal responses for later processing.

Design and procedure

Participants were tested individually in soundproof booths. The experiment comprised 52 trials divided in four blocks, one block for each combination of word type (concrete, abstract) and visual interference (DVN, control). The resulting design was a 2×2 within-subjects design. Two participants were randomly assigned to each of the 24 (4!) possible orders of presentation of these four blocks. The order of presentation of concrete and abstract lists within a block was determined at random.

Each trial began with the presentation of a row of dashes, which remained on screen until the participant initiated the trial by pressing the computer's mouse button. One second later, the DVN got going in the interference condition, whereas the screen merely went grey in the control condition. After one second, a five-word list was presented through the headset at a rate of one item every two seconds. Participants were instructed to merely look at the screen throughout the presentation of the list. After the last stimulus, the screen went white and a question mark prompted participants to recall the words in serial order. They were instructed to substitute the word *espacio* (blank) for any word they could not recall. There was a 16-s time limit to complete recall.

The 13 lists of each block were constructed for each participant by randomly selecting words from either the concrete set or the abstract set, with the constraint that every word appeared in five trials, once in each of the five possible positions within the lists. Experimental trials were preceded by six practice trials. Practice trials were constructed so that all the experimental stimuli appeared at least once. A brief rest period was established before each experimental block.

Results

Participants' responses were categorised into the following three categories: correct responses (correct words in the right position), order errors (words presented in the current list but recalled in the wrong position), and item errors, with this latter category subsuming omissions (*blank* responses), intra-experimental intrusions (words in the experimental sets but not presented in the current list), and extra-experimental intrusions (words that were not in the experimental sets). Percentages of responses within each category are shown in Table 1. To control for

Table 1. Percentage of correct responses, order errors, and item errors in Experiment 1 (standard deviation in parentheses).

Word type	Interference	Correct responses	Order errors	Item errors
Concrete	DVN	74.42 (14.35)	14.76 (10.21)	13.27 (8.71)
	Control	75.83 (15.84)	12.87 (10.17)	13.75 (10.40)
Abstract	DVN	69.71 (14.45)	15.46 (9.00)	18.14 (10.68)
	Control	72.56 (14.33)	12.92 (9.76)	17.18 (10.19)

Table 2. Statistical results for the 2 (word type) × 2 (interference) within-subjects ANOVA on the percentage of correct responses, order errors, and items error in Experiment 1.

	F(1, 47)	MSE	p	η_p^2
Correct responses				
Word type	14.199	53.830	0.000	0.232
Visual interference	4.898	44.504	0.032	0.094
Word type × interference	0.365	68.449	0.549	0.008
Order errors				
Word type	0.197	33.641	0.659	0.004
Visual interference	6.513	36.138	0.014	0.122
Word type × interference	0.092	53.967	0.763	0.002
Item errors				
Word type	24.804	33.332	0.000	0.345
Visual interference	0.132	20.952	0.718	0.003
Word type × interference	0.992	25.110	0.324	0.021

different conditions differing in the number of items recalled, percentages of order errors were calculated with respect to the number of list items recalled, rather than to the total number of responses (Murdock, 1976). Table 2 shows the statistical results of the analyses described below.

Percentages of correct responses were submitted to a 2 × 2 within-subjects analysis of variance (ANOVA) with word type (concrete, abstract) and visual interference (DVN, control) as factors. There was a main effect of word type, revealing that concrete words were better recalled than abstract words (concreteness effect = 3.99%, Cohen's d = 0.54). The main effect of visual interference was also significant, showing worse memory performance with DVN (interference effect = 2.13%, Cohen's d = 0.32). Importantly, however, there was no interaction between word type and visual interference, revealing equivalent concreteness effect across interference conditions (concreteness effect in the DVN condition = 4.71%, Cohen's d = 0.43; concreteness effect in the control condition = 3.27%, Cohen's d = 0.29). Because this lack of interaction is a key result for the present study, we used Bayes factor analysis to quantify the evidence supporting this interaction. More precisely, we evaluated the two models of interest, one with the two main effects and another that also included the interaction, by calculating their Bayes factors, BF_{10}. For each model, the BF_{10} value represents the strength of the evidence that data provide for the model under consideration (H_1) in relation to the evidence in favour of the null model (H_0). Here and throughout the rest of this paper, Bayesian analyses were conducted using JASP 0.8.6 (JASP Team, 2018) with default parameters (Morey & Rouder, 2015; Rouder, Morey, Speckman, & Province, 2012; for a friendly introduction to Bayes factor hypothesis testing and the JASP software package, see Wagenmakers, Love, et al., 2018; Wagenmakers, Marsman, et al., 2018). Results revealed that observed data were almost four times (63.6/16.3 = 3.9) more likely under the word type + visual interference model (BF_{10} = 63.6) that under the word type + visual interference + word type × visual interference model (BF_{10} = 16.3).

Regarding the percentages of order errors, the corresponding ANOVA showed a significant effect of visual interference (more order errors in the DVN condition; interference effect = 2.21%, Cohen's d = 0.37), but no interaction. Bayes factor analysis revealed no evidence for the model with interaction with respect to the null model ($BF_{10} < 1$). In turn, an ANOVA on the percentages of item errors showed a main effect of word type (more item errors with abstract words; concreteness effect = 4.15%, Cohen's d = 0.72). Again, no interaction between word type and visual interference was found. According to the Bayes factor analysis, observed data were 17246/5679 = 3 times more likely under the model with only the two main effects (BF_{10} = 17246) than under the model that also includes the interaction (BF_{10} = 5679).

Discussion

Results showed better recall for concrete words, thus showing the standard concreteness effect. There was also an effect of the presentation of DVN, with DVN resulting in worse memory performance. This effect seems to corroborate that participants followed the instruction to look at the screen during the presentation of the DVN. Importantly, the lack of interaction revealed that the presentation of DVN interference did not reduce the concreteness effect. These findings, thus, did not support the view that the concreteness effect in STM results from the generation of mental images.

Error analysis revealed that word type had a selective effect on item memory; a pattern that has been found in previous studies (Campoy et al., 2015; Walker & Hulme, 1999). The fact that word concreteness had an effect on the retention of item information without affecting the retention of order supports the assumption that item and order memory in verbal STM may rely on rather independent mechanisms (Burgess & Hitch, 1999; Nairne & Kelley, 2004; Roche, Tolan, & Tehan, 2011), and is consistent with the idea that lexical-semantic variables mainly affect item memory (Majerus, 2009; Romani et al., 2008). For its part, the presentation of DVN had a selective effect on order errors. This pattern contrasts with that previously obtained with attention-demanding concurrent tasks, which have been found to produce a detrimental effect in terms of both item and order errors (Campoy et al., 2015). The fact that the DVN did not generate more order errors for concrete words, which are imaginable, suggests that the visual interference caused a general, non-modality specific disruption.

Experiment 2

An aspect of Experiment 1 that deserves consideration is the fact that we used a closed set of experimental stimuli, with the same words appearing repeatedly across trials. In this situation, participants eventually learn the experimental word set and use this information at recall, thus reducing the number of extra-experimental intrusions (Roodenrys & Quinlan, 2000). Moreover, following the redintegration hypothesis (Hulme et al., 1997), it could be argued that it is easier to reconstruct the degraded traces when there is a limited pool of competing items. In Experiment 2, an open set of items was employed in order to increase item retention significance. As each item appeared only once throughout the experiment, performance had to rely more on item memory, eliminating the benefit of learning the words across trials as with a closed set. Because word concreteness seems to affect mainly item memory (Majerus, 2009), using open sets may increase the concreteness effect and, consequently, make it more sensitive to potential modulators, such as the irrelevant visual interference.

Method

Participants

Sixty undergraduate students from the University of Murcia participated in the experiment for course credit. Thirty participants were assigned to the DVN condition and the other thirty participants were assigned to a control condition without visual interference.

Stimuli and apparatus

We selected two sets of Spanish words from the LEXESP database (Sebastián et al., 2000), one comprising 70 concrete, high-imageability words, the other comprising 70 abstract, low-imageability words. All the words were trisyllabic nouns with the stress on the penultimate syllable. The two-word sets were globally matched for number of phonemes, and individually matched for word frequency and familiarity. A similar group of 30 trisyllabic nouns were chosen for practice trials. Further description of the word sets used can be found in Campoy et al. (2015, Experiment 3). Other materials were the same as those used in Experiment 1.

Design and procedure

The experiment consisted of two blocks of 14 trials, seven trials with concrete-word lists and seven with abstract-word lists. All the lists consisted of five words, with phonological similarity being controlled by not allowing two words from a list to share the first phoneme or a syllable in the same position. With this restriction, lists were constructed for each participant by selecting words from the specific set at random without replacement, so that each experimental word only appeared once. Other aspects of the procedure were the same as those in Experiment 1, with the difference that the design was mixed, as visual interference was manipulated between-subjects.

Results

Participants' responses in the memory task were classified as in Experiment 1 (see Table 3). Table 4 presents the statistical results of the ANOVAs described below.

Table 3. Percentage of correct responses, order errors, and item errors in Experiment 2 (standard deviation in parentheses).

Word type	Interference	Correct responses	Order errors	Item errors
Concrete	DVN	67.29 (12.66)	14.28 (9.65)	21.86 (9.54)
	Control	75.10 (14.10)	9.43 (8.24)	17.57 (10.33)
Abstract	DVN	60.67 (14.43)	14.28 (9.20)	29.67 (12.32)
	Control	67.33 (16.21)	11.14 (8.84)	25.00 (12.70)

Percentages of correct responses were submitted to a 2×2 mixed ANOVA with word type (concrete, abstract) as the within-subjects factor and visual interference (DVN, control) as the between-subjects factor. There was a main effect of word type, with concrete words being better recalled than abstract words (concreteness effect = 7.19%, Cohen's $d = 0.87$). There was also a main effect of visual interference, revealing worse memory performance in the DVN condition (interference effect = 7.24%, Cohen's $d = 0.55$). Importantly, there was no interaction between these two factors, suggesting an equivalent effect of concreteness in the DVN and the control conditions (concreteness effect in the DVN condition = 6.62%, Cohen's $d = 0.58$; concreteness effect in the control condition = 7.76%, Cohen's $d = 0.71$). Bayes factor analyses showed that observed data were almost four times (5575.8/1438.0 = 3.9) more likely under the model with only the two main effects ($BF_{10} = 5575.8$) than under the model that added the interaction ($BF_{10} = 1438.0$).

An equivalent ANOVA on the percentage of order errors showed a marginally non-significant main effect of visual interference (more order errors in the DVN condition; interference effect = 4.00%, Cohen's $d = 0.50$), but no interaction. The Bayes factor for the model that includes the interaction revealed no supporting evidence with respect to the null model ($BF_{10} < 1$). Finally, the corresponding ANOVA on the percentages of item errors yielded a main effect of word type (more item errors for abstract words; concreteness effect = 7.62%, Cohen's $d = 1.31$). Again, there was no interaction between word type and visual interference. Bayes factor analysis revealed that data were 3.993/1.107 = 3.6 times more likely under the word type + visual interference model ($BF_{10} = 3.993 \times 10^7$) than under the model that also included the interaction ($BF_{10} = 1.107 \times 10^7$).

Table 4. Statistical results for the 2 (word type) × 2 (interference) mixed ANOVA on the percentage of correct responses, order errors, and items error in Experiment 2.

	$F(1, 58)$	MSE	p	η_p^2
Correct responses				
Word type	24.770	62.602	0.000	0.299
Visual interference	4.463	352.216	0.039	0.071
Word type × interference	0.157	62.602	0.694	0.003
Order errors				
Word type	0.623	35.307	0.433	0.011
Visual interference	3.792	126.470	0.056	0.061
Word type × interference	0.617	35.307	0.435	0.011
Item errors				
Word type	59.202	29.418	0.000	0.505
Visual interference	2.659	226.007	0.108	0.044
Word type × interference	0.037	29.418	0.848	0.001

Discussion

In contrast to Experiment 1, we used an open set of to-be-remembered words in Experiment 2, so that each experimental stimulus appeared only once during the task. We expected that memory performance in this situation would depend more crucially on item memory; consequently, the advantage of concrete words over abstract ones would increase, so that, hopefully, the procedure would be more sensitive to detect differences in the concreteness effect between interference conditions. Despite this key difference in the procedure, the pattern of results obtained in Experiment 2 was equivalent to that in Experiment 1. We found the expected effect of word concreteness, which was almost exclusively due to differences in the number of item errors. The introduction of visual interference, for its part, had a detrimental effect on performance, with DVN affecting mainly order errors. Crucially, the concreteness effect was not reduced in presence of visual interference and, thus, we found no evidence supporting the idea that the concreteness effect in STM emerges from the generation and maintenance of visual representations.

General discussion

This study investigated the possibility that the concreteness effect in STM is due to the generation and maintenance of visual representations. To this aim, two experiments analysed the consequences of introducing a form of visual interference (DVN), on the immediate serial recall of concrete and abstract words. Previous studies have shown that the presentation of DVN interferes with the generation of mental images (Dean et al., 2005; Toms et al., 1994), and results in the elimination of the standard concreteness effect in episodic LTM (Parker & Dagnall, 2009). The two experiments described in the present work, however, showed a concreteness effect that was not modulated by the introduction of the visual noise. Across the two experiments, the presentation of DVN had a global impact on memory performance, so the lack of modulation of the concreteness effect cannot be attributed to participants not paying attention or deliberately ignoring the DVN display. These findings, therefore, provide no evidence for the view that the concreteness effect in STM emerges from the generation and maintenance of visual representations.

Our finding that the presentation of DVN did not reduce the concreteness effect in immediate serial recall contrasts with the results reported in the LTM domain by Parker and Dagnall (2009), which showed a reversion of the concreteness effect with the introduction of DVN. These contradictory results may be a consequence of the fact that participants in a LTM task under intentional learning instructions (as in Parker & Dagnall, 2009) are prone to engage in elaborative rehearsal and strategic encoding in order to maximise performance in the announced subsequent memory test. This elaborative rehearsal may include the generation of mental images, which would be affected by the presentation of the DVN. In contrast, the concreteness effect in STM might rely on automatic processes and not elaborated strategies, as suggested by the observation that the introduction of concurrent, attention-demanding tasks does not reduce the concreteness effect in STM (Campoy et al., 2015).

In relation to previous STM studies observing the consequences of visual interference on the concreteness effect, the present results are congruent with those obtained by Campoy et al. (2015). In that study, the visual interference was associated with attention-demanding concurrent tasks and no modulation of the concreteness effect was found as a consequence of the introduction of the secondary tasks. On the other hand, however, our results contrast with those of Ueno and Saito (2013), who found a (marginally significant) reduction of the concreteness effect in an immediate serial recall task when DVN was presented. Some of the characteristics of the procedure employed by Ueno and Saito may be at the origin of this discrepancy. Firstly, Ueno and Saito employed 8-word lists, a list length that exceeds STM capacity (Cowan, 2010) and that could have boosted the contribution of LTM processes. Secondly, Ueno and Saito explicitly instructed participants to not creating visual images of the items, and these instructions were repeated every four trials. Generating visual images of the meaning of the words is not a very common strategy in immediate serial tasks, according at least to participants' reports (Logie, Della Sala, Laiacona, Chalmers, & Wynn, 1996; Morrison, Rosenbaum, Fair, & Chein, 2016). Morrison et al. (2016), for example, found that less than the 5.5% of the participants reported to have created visual images. Thus, we may speculate whether making the visual strategy so explicit might have caused the paradoxical effect of stimulating its use beyond what would be expected in standard conditions.

As mentioned, the fact that the presentation of DVN did not differentially affect the immediate serial recall of concrete and abstract words in the present experiments suggests that the generation and maintenance of visual representations do not play a crucial role in the concreteness effect. Which could be, then, the origin of the concreteness effect? Two possible explanations may be posited. First, the concreteness effect in STM could be a consequence of LTM participation through redintegration processes (Hulme et al., 1997; Schweickert, 1993). According to this interpretation (Walker & Hulme, 1999), immediate serial recall of lists of words would depend on the temporary encoding and maintenance of phonological representations mainly, but also of semantic representations. During the retention phase, those STM representations could suffer from a certain level of degradation, and so LTM information could be used to redintegrate them. It has been traditionally assumed that this reconstruction takes place at retrieval (Walker & Hulme, 1999), but it can be argued that it can also take place during the retention interval every time a representation is reactivated as a consequence of a maintenance mechanism (such as subvocal rehearsal or attentional refreshing). In this sense, the concreteness effect could be due to concrete words generating richer short-term semantic traces (Walker & Hulme, 1999), and perhaps also because long-term representations of concrete words are more accessible during the redintegration process.

An alternative account is based on the language-based models of verbal STM, according to which the maintenance of verbal representations in STM relies on the activation of long-term knowledge across different representational levels (phonological, lexical, and semantic) within the linguistic system (Acheson & MacDonald, 2009; Gupta, 2009). Even though phonological representations may play the main role in standard verbal STM tasks involving serial recall of semantically unrelated words, activation of lexical-semantic representations may contribute to maintenance of phonological representations through mutual interactions between the different representation levels (Savill, Ellis, & Jefferies, 2017). The contribution of the semantic level of representation in verbal STM is illustrated, for example, in studies with semantic dementia patients, who show worse short-term maintenance of the phonological form of the words whose understanding is damaged (Hoffman, Jefferies, Ehsan, Jones, & Lambon Ralph, 2009; Patterson, Graham, & Hodges, 1994). According to this view, the concreteness effect would emerge because, compared to concrete words, information activated in the semantic level by abstract words is poorer, and, thus, contributes less to the maintenance of representations in the phonological level.

There are two main differences between the two proposed interpretations. First, the redintegration-based explanation assumes the existence of different representational substrates for STM and LTM, as stated by traditional STM accounts (Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1974). On the other hand, the explanation based on the language-based models of verbal STM is in line with more modern (and, probably, more biologically plausible) models according to which STM and LTM would share the same representational substrate but would differ in terms of representations being more or less active and/or accessible (Cowan, 1995; Oberauer, 2002, 2009; Ruchkin, Grafman, Cameron, & Berndt, 2003). The second difference is that the redintegration process would be a partially explicit mechanism, as it would take place as part of conscious reactivation and retrieval operations, and would be discrete in time, as it would take place at specific moments, every time an item is reactivated or recalled. On the contrary, from the point of view of the language-based models, the concreteness effect would be a consequence of the internal dynamics of the representational system, generated through multiple existing interconnections between the different levels of representation and, therefore, could be seen as a mainly implicit, continuous in time, mechanism.

Despite these differences, both explanations have a common aspect, that is, the concreteness has a direct effect on item memory, but not on order memory (although order memory can be indirectly affected). This is congruent with the present study, in which concreteness had an effect on item errors but not on order errors. Similar results have been found in previous studies about the concreteness effect on STM (Campoy et al., 2015; Romani et al., 2008; Walker & Hulme, 1999), and on other lexical/semantic effects in verbal STM (Jefferies, Frankish, & Lambon Ralph, 2006).

One last finding that deserves attention is the selective effect of DVN on order errors, which has been found in both experiments (although the effect in Experiment 2 was marginally non-significant). This selective effect on order errors contrasts with a previous study, which showed a decline in performance both in terms of order and item recall when attention-demanding concurrent tasks (with and without visual interference) were introduced (Campoy et al., 2015). This difference is in line with the broadly accepted idea that DVN does not pose a significant load in attentional terms (St Clair-Thompson & Allen, 2013). However, the present findings contradict previous studies that have failed to find a DVN effect on the immediate serial recall of verbal items (St Clair-Thompson & Allen, 2013; Ueno & Saito, 2013). Although we cannot offer a satisfactory explanation on this discrepancy, we can speculate that it might be due to some differences related with the DVN presentation procedure, or to the way in which participants were instructed to attend to the screen during its presentation.

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